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Research on Fire Safety Evacuation in a University Library in Nanjing

Ming-xin LI^{a,b}, Shun-bing ZHU^{a,b}, Jing-hong WANG^{a,b}, Zheng ZHOU^{a,b,*}

^aJiangsu Key Laboratory of Hazardous Chemicals Safety and Control, Nanjing 210000, China

^bCollege of Safety Science and Engineering, Nanjing Tech University, Nanjing 210000, China

Abstract

To research the fire peril arrival time and evacuation situation when fire extinguishing system fails, in this work Pyrosim and Pathfinder software were used to simulate the spread of smoke and human evacuation in a university library in Nanjing during fires. Through the comparative analysis of the temperature, smoke layer height, the visibility, CO concentration and FED value, the simulation results show that, the risk time of the library is 280s, on the fire scale of 4MW; the risk time of reading room is 125s, on the fire scale of 8MW. The evacuation simulation results indicate that the evacuation time of the entire library and reading room is 411s and 165s respectively. Finally, the fire safety of the library is evaluated by comparing the risk time and evacuation time. It is concluded that the exit of each layer is the first to reach the dangerous state; the direction of the hazardous area is also the direction of safe evacuation. The risk time of the library and the reading room, is the time when the height of smoke down to 2m. Therefore, the staff activity height, smoke volume and detection alarm and other factors, should be considered in the system design of smoke control.

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1. Introduction

The library is constructed in an unusual structure, with complex functions and large fire loads. After the fire, it can cause casualties, unpredictable property losses and political impact [1]. Moscow's second largest library burst into flames on January 30, 2015. That's created about 1,000 square meters of roof collapse; three floors of the library burned and destroyed lots of precious ancient books and political literature. In the 1980s, some developed countries began to study the buildings performance-based fire safety design method systematically. With the development of the computer technology, more than 20 kinds of evacuation models and the corresponding calculation software have been developed. [2] Have Pyrosim, Pathfinder, STEPS, Analogic and so on. Feizhou Huo [3] studied the simulation of human evacuation in high-rise building fire. It indicates that the risk perception and emotional state of the individual will be affected in the case of a real fire; Sanjay Kumar Khattri 's [4] research from small-scale tunnel fire simulations to predicting fire dynamics in realistic tunnels, show that the wind speed exert great influence on the parameters; Yue Z, Jin RG et al [5] numerical simulation of dormitory fire by using FDS; Chen JW et al [6] studied the relationship between the emergency exit and the number of evacuees; Fang Z et al [7] using the spatial grid evacuation model it has developed, summarizes the relationship between evacuation speed for personnel and crowd density.

In this work, Pyrosim software was used to modeling a university library in Nanjing. Through comparative analysis on the temperature, smoke layer height, the visibility, CO concentration and FED value, the risk time of the library is obtained. Pathfinder software was used to simulate the human evacuation of the reading room and the whole library; it is concluded that the exit of the third floor is the most dangerous area for safe evacuation, and puts forward some suggestions on the

* Corresponding author. Tel.: +86-159-5160-1152.

E-mail address: 15951601152@163.com

system design of smoke control of the library, which provides a theoretical basis for the fire safety evacuation when fire extinguishing system fails.

2. Basic principles of safe evacuation

2.1. Judgment basis for the fire peril arrival time

To predict the fire development process, the predicted result of fire simulation and relevant parameters is used in, obtain the fire peril arrival time. Through consulting correlative literature [8], get the following criteria.

(1) Visibility

Limit of visibility for personnel in small space is 5m; in large space is 10m [9].

(2) The height and the temperature of the smoke

When the smoke layer more than 2m above ground or floor, it is considered that the temperature of the human tolerance limits is 200°C. Also, it is safe that the temperature of the inhalable air under 60°C, according to the study.

(3) CO

Table 1. The effect of CO on the human body

Content ($\times 10^{-6}$)	Exposure time	Harm effect
100 (0.01%)	Within 8h	No feeling
400-500 (0.05%)	Within 1h	No feeling
600-700 (0.07%)	Within 1h	headache, nausea, breathing disorders
1000-2000 (0.2%)	Within 2h	Consciousness, breathing disorders, coma, die within 2h
3000-5000 (0.5%)	Within 20-30min	Death
10000 (1%)	Within 1min	Death

In this work, the CO concentration below 3000×10^{-6} ppm is regarded as the critical value for judging the danger.

(4) FED toxicity standards

The toxic smoke is evaluated using FED or FEC, which is calculated by the evaluation software, based on the method of the fitted concentration of smoke components. When the value of FED is less than 0.1, it is safe for those exposed to it. When FEC is greater than 1.0, it will cause harm to most people [10]. When evaluating, the building is considered unsafe if the human evacuation time exceeds the time for the FED reaches 0.1.

2.2. The method of determining the Required Safe Evacuation Time

In the event of fire, whether the personnel can safe evacuation, depending on the relative size of the available safe evacuation time ASET and the required safe evacuation time RSET [11]. ASET: the fire danger to the people that the time was taken, which is the time of danger. RSET: the time required for personnel in hazardous areas to evacuate and arrive safe area. If it can leave the staff to a safe area before the fire peril arrival time, the building fire safety design is considered safe for evacuees.

$$RSET = t_{alarm} + t_{resp} + t_{move} \quad (1)$$

$$t_{resp} = t_{rec} + t_{react} \quad (2)$$

Where: t_{alarm} is the fire alarm time; t_{resp} is the staff response time; t_{move} for evacuation time; t_{rec} is the recognition time; t_{react} is the reaction time.

"Rules for Site Test and Determinant of Fire Products "(GA588-2005) stipulate the typical infrared flame detector output fire alarm signal should be within 30s; other types of detectors did not make clear detailed provisions. Owing to the high runtime, improper maintenance and management, a longer response time, some detection system detection time more than 30s, some more than 1min. The t_{alarm} is set as the 40s.

t_{rec} Is the period after the alarm signal has not yet begun to respond. Considering readers in the library are young

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